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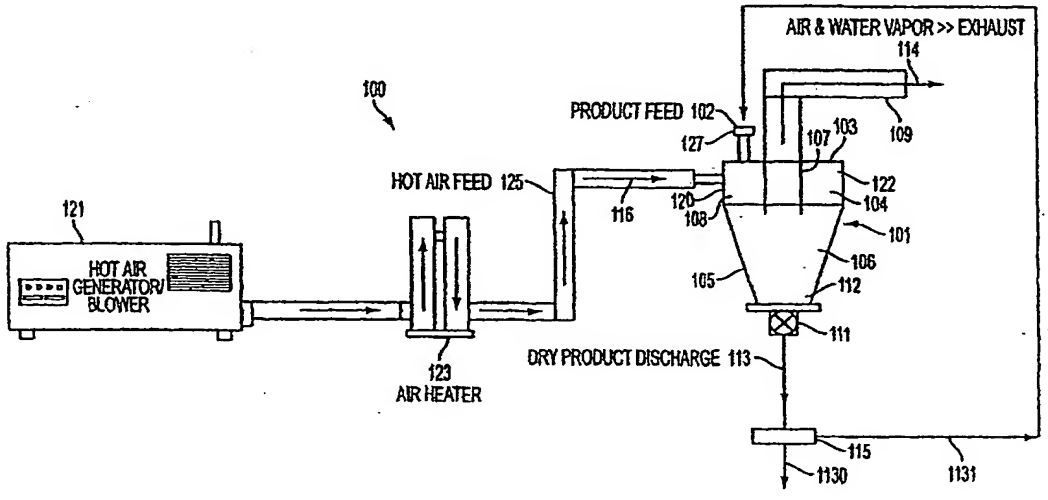

(57) Abstract: A single-stage process for drying, roasting, and grinding of green coffee beans in a single unit operation in a continuous manner. Heat-treated and ground coffee beans having savory flavor and aroma are achieved in a unique process described herein that combines all these different treatments in a single-stage operation.

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PROCESS FOR SINGLE-STAGE HEAT TREATMENT AND GRINDING OF COFFEEE BEANS, AND PRODUCTS THEREOF

Cross-Reference To Related Applications

This application is a continuation-in-part of prior application number 10/736,595, filed December 17, 2003, which is incorporated herein by reference in its entirety.

Technical Field

The invention generally relates to a process for single-stage drying, roasting and grinding of coffee beans and similar particulate edible materials.

Background Art

Coffee beans are derived from coffee cherries produced by the coffee plant. Once coffee cherries have been picked, the fleshy pulp is removed to expose the coffee bean (the seed). There are two general methods of preparing green coffee beans for market: the "dry" process and the "wet" process. In the dry process, ripe coffee cherries are left to dry in the sun until the shriveled husk (pericarp and endocarp) can be cracked open. The wet process involves removing the pulp with rollers. The parchment (endocarp) is then removed by soaking the beans to allow the natural enzymes to break down the remaining mucilage (mesocarp), then washing, drying and dehulling. The green coffee beans (generally at 10-13% moisture content) obtained are then graded and packed.

The green coffee beans are roasted before consumption to develop the characteristic and desired flavor and aroma of the coffee product. When roasted, chemical reactions occur within the coffee beans that transform the beans into the desired state of pyrolysis. The roasted coffee beans acquire a darker hue and lose moisture during the roasting process. The first stage of the roasting process is a drying step wherein moisture is driven out of the bean allowing the bean temperature to subsequently rise to the point where first the endothermic and then the exothermic roasting reactions occur. Roasting is a sensitive process requiring skill in generating the coffee flavors without adversely affecting the balance of taste. Uniform heating of the coffee beans is important in this respect, so that the coffee beans experience essentially the same heat history during roasting. In previous efforts to provide more uniform heating of the coffee beans during roasting, coffee beans have been roasted in large revolving drums which are constantly mixing the beans, or in fluidized beds and the like, such that the beans are

heated while suspended in air. Generally the roasting process is ended with a quenching step (water spray) and cooling of the beans in air.

After roasting and at some point before consumption, the coffee beans, which at that juncture generally have a 2-5% moisture content, are ground into smaller particles of generally uniform size to facilitate extraction of soluble solids (e.g., carbohydrates, sugars and organic acids, etc.) and flavor components from the coffee product during brewing. In conventional practice, it has been important to assure that bean moisture is below 6% and that the beans have had time to cure (harden and equilibrate the distribution of quench moisture within the bean) sufficiently to assure that even crushing and cutting of the beans is possible during grinding and that the coffee does not stale rapidly after grinding. Some roasted coffee beans are sold intact after roasting, and they are ground by consumers themselves before brewing. However, there is a large market and need for preground roasted coffee beans. Coffee bean processors grind roasted coffee beans and pack the ground product in airtight pouches or cans into which inert gas is commonly injected to displace oxygen before sealing the package or the package is evacuated such that flavor loss in the ground coffee beans from oxidation is minimized. The preground coffee products offer the consumer added convenience as they eliminate the need to grind the coffee beans or need for equipment for that purpose. Roasted coffee beans also are ground by coffee bean processors for use in the manufacture of some instant coffee products. In making such instant coffee products, roasted coffee beans are ground and then brewed in relatively large production quantities, and the brewed product is either freeze-dried or spray-dried to shelf-stable moistures in granular or powder form. Consequently, commercial processes are used and needed by coffee bean processors for both roasting and grinding green coffee. Moreover, the coffee bean processing business is competitive, so economic factors such as capital costs, operation costs and production yields are important. An arrangement for making roasted ground coffee in fewer process steps, no curing requirement and with less equipment requirements would be beneficial and desirable. The present invention addresses the above and other needs in an efficient and economically-feasible manner.

Disclosure of Invention

This invention provides a process for drying, roasting, and grinding green coffee beans in a single unit operation. This process combines and executes all these different thermal and physical coffee bean treatments in a single-stage operation that can be conducted in a continuous and short duration manner. The heat-treated and ground coffee beans obtained by this single-stage process have savory and at least mild coffee flavor and aroma.

In one embodiment, a single-stage coffee bean heat treatment and grinding process is provided for drying and roasting green coffee beans. In a preferred embodiment, the green coffee beans which can be dried and ground in the single-stage process have a moisture content generally in the range of about 6% to about 50%, particularly about 8% to about 45%, and more particularly about 10% to about 40%.

In one particular embodiment of this invention, a coffee bean heat treatment and grinding process is provided in which compressed heated air, and green coffee beans premoistened to about 20 to about 50%, particularly about 25 to about 35%, moisture content, are separately introduced into an enclosure that includes a truncated conical shaped section. In another particular embodiment, green coffee beans having a moisture content of about 8% to about 15%, particularly about 10% to about 15%, are used as the feed material subjected to the single-stage drying, roasting and grinding process. In either scenario, after introduction into the enclosure, the compressed heated air travels generally along a downward path through the enclosure until it reaches a lower end thereof. The air flows back up from the lower end of the enclosure in a central region thereof until exiting the enclosure via an exhaust duct. The green coffee beans are separately introduced into an upper end of the enclosure, and they become entrained in the heated air traveling downward through the enclosure until reaching the lower end of the enclosure.

During this movement of the coffee beans from the upper end of the enclosure down to the lower end thereof, the coffee beans are thermally and physically processed in mutually beneficial ways. The green coffee beans are dehydrated and roasted by the heated air in which they are suspended in such a dynamic air flow system. During the same unit operation, the coffee beans are disintegrated into small particles in an extremely short period of time. Significant amounts of the introduced green coffee beans

can be dried, roasted, and ground before reaching a lower end of the enclosure.

Consequently, a solid particulate product including dried, roasted and ground coffee beans is discharged and recovered from the lower end of the enclosure, while air, moisture vapor, carbon dioxide and other volatile compounds and gases released from the coffee beans from drying and roasting are exhausted from the system via the exhaust duct. In one particular embodiment, the enclosure is a two-part structure including an upper cylindrical shaped enclosure in which the compressed heated air and green coffee beans are separately introduced, and the cylindrical enclosure adjoins and fluidly communicates with a lower enclosure having the truncated conical shape that includes the lower end of the overall structure from which the processed feed material is dispensed.

The single-stage process for drying, roasting, and grinding of green coffee beans in a continuous manner in a single unit operation according to embodiments of this invention offers numerous advantages over conventional schemes for roasting and grinding coffee beans. For one, there is the elimination of the need for conducting separate drying, roasting, and grinding processes in different equipment such as conventionally used in processing moistened green coffee beans. Elimination of the curing step intermediate between roasting and grinding significantly simplifies the process and avoids any need for storage of roasted beans. Additionally, the process of this invention can be operated in a continuous mode as the compressed heated air is continually exhausted from the system after entraining the coffee beans downward through the enclosure to its lower end where they are deposited, and roasted and ground coffee bean product material can be withdrawn from the lower end of the enclosure in an air-tight manner, such as by using a rotary air-lock. These advantages reduce process complexity, production time, and production costs. Also, product quality enhancements are attained. The drying, roasting and grinding of the moistened coffee beans in the same equipment can enhance flavor and aroma generation as compared to roasting and grinding them in separate processes performed in separate equipment. It is additionally believed that these processes can also be combined in a manner that avoids the retention of undesirable flavor notes because of the shortened timeframe for the roasting process induced by the simultaneous pulverization and virtually instantaneous purging of reaction products. In a further embodiment, a higher yield and more uniform product

color development is made possible as part of grinding inside the roasting enclosure by controlling particle size distribution via screening or other classification procedure performed on the product stream and recycling coarser fraction coffee beans needing more grinding.

For purposes herein, "drying" means dehydrating, i.e., a reduction in moisture content; "roasting" means heating a fruit seed like coffee sufficient to induce pyrolysis; and "grinding" a particle means crushing, pulverizing, abrading, wearing, or rubbing the particle to break the particle down into smaller particles and/or liberate smaller particles from the particle, and/or between a moving particle and a static surface.

This invention also relates to the roast and ground coffee products obtained by processes embodied herein. Although this invention is illustrated for processing coffee beans, it will be appreciated that the methods and equipment arrangements of this invention are generally applicable to other edible fruit beans, such as cocoa beans.

Brief Description of Drawings

Other features and advantages of the present invention will become apparent from the following detailed description of preferred embodiments of the invention with reference to the drawings, in which:

FIG. 1 is a schematic view of a system useful for processing coffee beans according to an embodiment of this invention.

FIG. 2 is a cross sectional view of the cyclone unit used in the processing system illustrated in FIG. 1.

The features depicted in the figures are not necessarily drawn to scale. Similarly numbered elements in different figures represent similar components unless indicated otherwise.

Detailed Description of the Preferred Embodiments

Preferred embodiments will be described below with specific reference to unique single-stage process for drying, roasting, and grinding of green coffee beans in one unit operation. In general, the single-stage process is implemented on a cyclonic type system that may be operated in a manner whereby the coffee beans may be thermally and physically acted upon at the same time within the same processing unit in a beneficial

manner. A dried, ground and roasted coffee product is obtained in granulated form (i.e., a dry flowable solid particulate). The granular product has organoleptic properties associated with conventional ground coffee, and is provided in a more stable form for ease of storage and handling until it is used in coffee brewing or other in other consumable products.

Referring to FIG. 1, an exemplary system **100** for handling green coffee beans according to a process embodiment of this invention is shown. Cyclone **101** is a structural enclosure comprised of two fluidly communicating sections: an upper cylindrical enclosure **103** defining a chamber **104**; and a lower truncated conical shaped enclosure **105** that defines a cavity **106**. Both the upper and lower enclosures are annular structures in which solid wall or shell encloses an interior space. In this illustration, the upper enclosure **103** has a generally uniform cross-sectional diameter, while the lower enclosure **105** tapers inward towards its lower end **112**. In a non-limiting embodiment, the taper angle α of lower enclosure **105** may range from about 66 to about 70 degrees. For purposes herein, the terminology "enclosure" means a structure that encloses a chamber, cavity, or space from more than one side.

Compressed heated air **116** and wet green coffee beans **102** are separately introduced into the cyclone **101** at the upper enclosure **103**. The processed coffee beans are discharged as a solid particulate **113** from the lower end **112** of the cyclone **101**. A valve mechanism **111**, such as a rotary valve or rotary air-lock, is shown that permits extraction of dried, roasted ground coffee product from the cyclone without interrupting continuous operation of the system and which minimizes leakage of the heated air from the cyclone **101**. If the cyclone **101** is operated without an air-lock or the like at the bottom discharge end of the cyclone **101**, the system generally will run less efficiently as heated air will be forced out of the lower end **112**, which will need to be compensated for in the air feed rate. Air, moisture vapor and other gaseous products of the roasting process released from the coffee beans during heat treatment within the cyclone **101**, is exhausted as exhaust gases **114** from the cyclone via sleeve **107** and exhaust duct **109**. Some silver skin (bean chaff) is liberated from the coffee beans during their processing in the cyclone and gets eliminated with the exhaust gas stream **114**. The exhaust gas stream **114** optionally may be particle filtered, and/or scrubbed to strip out certain compounds, such as using a separate scrubber module (not shown), e.g. a packed bed

type scrubber, before it is vented to the atmosphere. Sieving device **115** is optional, and is described in more detail later herein. Generally, it can be used to recycle oversize product in particulate product **113** back into the coffee bean feed that is introduced into the cyclone **101**.

To introduce the compressed heated air **116** into cyclone **101**, an air pressurizing mechanism **121**, such as a blower or air compressor, generates a high volume, high velocity compressed air stream that is conducted via hot air ducting **125** through an air heater **123**, and from there is introduced into upper enclosure **103** of cyclone **101**. For purposes herein, the term "heated air" refers to air heated to a temperature above ambient temperature, e.g., above 25°C. The term "compressed air" refers to air compressed to a pressure above atmospheric pressure, e.g., above 14.7 psia (lb./inch^2 absolute). The term "compressed heat air" refers to air having both these characteristics. The compressed heated air **116** is introduced into chamber **104** substantially tangentially to an inner wall **108** of the upper enclosure **103**. This can be done, for example, by directing the heated air stream **116** to a plurality of holes **120** (e.g., 2 to 8 holes) circumferentially spaced around and provided through the wall **108** of the upper enclosure **103** through which the heat stream is introduced. Deflection plates **122** can be mounted on inner wall **108** of upper enclosure **103** for deflecting the incoming stream of heated air into a direction substantially tangential to the inner wall **108** according to an arrangement that has been described, for example, in U.S. patent appln. publication no. 2002/0027173 A1, which descriptions are incorporated herein by reference. The heated air may be introduced into the upper enclosure **103** of cyclone **101** in a counter-clockwise or a clockwise direction.

The introduced air **116** is further pressurized cyclonically in the chamber **104** and cavity **106**. Due to the centrifugal forces present in the cyclonic environment, the pressure nearer the outer extremities of the cavity **106** is substantially greater than atmospheric pressure, while the pressure nearer the central axis of the cavity **106** is less than atmospheric pressure. As shown in FIG. 2, as a non-limiting illustration, after being introduced into upper enclosure **103**, the compressed heated air **116** spirals or otherwise travels generally along a large downward path as a vortex 13 through the upper enclosure **103** and the lower conical shaped enclosure **105** until it reaches a lower end **112** thereof. In this illustration, near the lower end **112** of the cavity **106** defined by the inner walls **123** of lower enclosure **105**, the downward direction of the air movement is reversed, and

the air (and moisture vapor and other gaseous products released from the coffee beans during heat treatment within the cyclone **101**) whirls back upwardly as a smaller vortex **15** generally inside the larger vortex **13**. The smaller vortex **15** flows back up from the lower end **112** of the lower enclosure **105** in a central region **128** located proximately near the central axis **129** of the cyclone **101** and generally inside the larger vortex **13**. The smaller vortex **15** flows upward until exiting the enclosure via sleeve **107** and then exhaust duct **109**.

A vortex breaking means (not shown) optionally can be interposed below or inside the lower end **112** to encourage the transition of the larger vortex **13** to the smaller vortex **15**. Various vortex breaking arrangements for cyclones are known, such as the introduction of a box-shaped enclosure at the bottom of the conical enclosure.

The green coffee beans **102** are separately introduced into upper enclosure **103**. The introduced coffee beans drop gravitationally downward into chamber **104** until they become entrained in the heated air vortex **13** within cyclone **101**. Preferably, the coffee beans are introduced into upper enclosure **103** in an orientation such that they will fall into the cyclonic vortex **13** generated within cyclone **101**, where located in the space between the sleeve **107**, and inner wall **108** of the upper enclosure **103**. This feed technique serves to minimize the amount of coffee beans that may initially fall into extreme inner or outer radial portions of the vortex where the cyclonic forces that the coffee beans experience may be lower.

The entrained coffee beans travel in the vortex **13** of heated air that spirals downward through the lower enclosure **105** until reaching the lower end **112** of the lower enclosure **105**. During this downward flow path, the green coffee beans are dehydrated and roasted by the heated air in which they are suspended in such a dynamic air flow system. They also are ground during the downward flow path. The various dehydration, roasting, and grinding effects on the coffee beans may occur at different respective times, and/or several of the effects may occur simultaneously at a particular point or points in time, during the downward flow path of the coffee beans through the cyclone. While not desiring to be bound to any theory, it is thought that the pressure-gradient and coriolis forces across, cavitation explosions, and the collision interaction between the coffee bean particles entrained in the high-velocity cyclonically pressurized air are violently disruptive to the physical structure of those beans. Alternatively, or in addition thereto,

the centrifugal force of the vortex moves the beans forcefully against inner walls **108** and **123** of the enclosure. These modes of attrition, individually or in combination, or other modes of attrition that may occur within the cyclone which may not be fully understood, bring about comminuting (grinding) of the coffee beans concurrent with drying and roasting of them. As a result, during this movement of the coffee beans from the upper enclosure **103** down to the lower end **112** of the lower enclosure **105**, the coffee beans are thermally and physically processed in beneficial ways.

For purposes herein, the "single-stage" treatment performed on the coffee beans encompasses the option of recycling a portion or all of the discharged product back through the cyclone for one or more additional passes therethrough. For instance, in a further embodiment of the invention, the discharged solid particulate product **113** can be screened, such as using a sieve, such as a screen sieve or other suitable particulate separation/classifying mechanism **115**, to sort and separate the finer fraction of ground coffee beans **1130** in the solid particulate product **113** that have particle sizes meeting a size criterion, such as being less than a predetermined size, which are suitable for post-grinding processing, from the coarser product fraction **1131**. The coarser (oversize) product fraction **1131** can be recycled by re-introducing it into the upper enclosure of the cyclone for additional processing therein. A conveyor (not shown) could be used to mechanically transport the recycled material back to feed introducing means **127** or other introduction means in upper enclosure **103** of cyclone **101**. Alternatively, the entire stream of discharged solid particulate product can be passed back through the cyclone **101** one or more times for further processing. Also, feed introducing means **127** may be an inclined conveyor (not shown), which transports wet mustard bran feed from a lower location up to and into chamber **104** of the cyclone **101** at the upper enclosure **103**. Additionally, even if an acceptable size of grind coffee beans is obtained, if a deeper roast is desired, those ground coffee beans can be re-introduced into the system to receive additional roasting and grinding.

It will be appreciated that sleeve **107** can be controllably moved up and down to different vertical positions within cyclone **101**. In general, the lower sleeve **107** is spaced relative to the cavity **106**, the smaller the combined total volume of the cyclone **101** which is available for air circulation. Since the volume of air being introduced remains constant, this reduction in volume causes a faster flow of air, causing greater cyclonic

effect throughout cavity **106** and consequently causing the coffee beans being ground to circulate longer in the chamber **104** and the cavity **106**. Raising the sleeve **107** generally has the opposite effect. For a given feed and operating conditions, the vertical position of sleeve **107** can be adjusted to improve process efficiency and yield.

Also, a damper **126** can be provided on exhaust duct **109** to control the volume of air permitted to escape from the central, low-pressure region of cavity **106** into the ambient atmosphere, which can affect the cyclonic velocities and force gradients within cyclone **101**. Other than the optional damper, the unit **101** generally requires no moving parts for operation.

By continually feeding coffee beans into cyclone **101**, a continuous throughput of roasted and grind coffee bean product material **113** is obtained. A non-limiting example of a commercial apparatus that can be operated in a continuous manner while processing coffee beans according to processes of this invention is a WINDHEXE apparatus, manufactured by Vortex Dehydration Systems, LLC, Hanover Maryland, U.S.A. Descriptions of that type of apparatus are set forth in published U.S. patent appln. publication no. 2002/0027173 A1, which descriptions are incorporated in their entirety herein by reference.

The cyclonic system **100** provides very high heat transfer rates from hot air to beans for roast flavor and color development, and mechanical energy to crack and granulate roasted beans as they descend through the conical section of the dryer. The coffee bean product exiting the cyclone **101** exhibits roasted and ground coffee flavors and aromas and appearance. The one-stage process offers numerous advantages over conventional schemes for roasting and grinding coffee beans in terms of providing a satisfactory quality ground coffee product while eliminating the need for separate drying, roasting, and grinding processes and equipment that are conventionally used in processing of market grade (e.g., about 10-13% moisture) beans or green beans moistened for the purpose of pre-roast treatments like steaming or decaffeinating.

In one non-limiting process scheme according to the invention for processing coffee beans, the introduction of the heated air comprises supplying compressed heated air at an inlet pressure within the range of from about 10 psig (lb./inch^2 gauge) to about 100 psig, particularly from about 15 psig to about 60 psig, and more particularly from about 20 psig to about 55 psig. The heated air is introduced into the cyclone at a

temperature within the range of about 300°F to about 700°F, more particularly about 375°F to about 675°F, and more particularly about 400°F to about 650°F. The volumetric introduction rate of the heated air into the cyclone is within the range of from about 500 cubic feet per minute (CFM) to about 10,000 CFM, particularly about 1,000 CFM to about 10,000 CFM, and more particularly from about 1,500 CFM to about 3,000 CFM. The feed rate of the coffee beans can vary, but generally will be in the range of about 1 to about 300 pounds per minute (lbs./min.), particularly about 1 to about 50 lbs./min, and more particularly about 1 to about 5 pounds per minute, for about a 1 to about a 10 foot diameter (maximum) cyclone. The cyclone diameter may be, for example, from about 1 to about 10 feet in diameter, and particularly about 1 to about 6 feet in diameter

For purposes of this application, the term "green coffee beans" refers to unroasted coffee beans (seeds) that have been separated from coffee cherry pulp and dehulled. The green coffee beans may be used in their original dehulled raw form, or alternatively they may be further treated before usage in manner which does not effect roasting of them. For instance, the green coffee beans may also be moisturized, steamed, and/or decaffeinated, such as using conventionally known techniques for such respective purposes (e.g., see General Foods Corp.'s U.S. Pat. No. 4,255,461).

The green coffee beans that can be used in the process of this invention can be derived from coffea arabica, coffea canephora (Robusta), or other varieties of coffee plants that bear seeded fruit. The green coffee beans optionally can be flavor-modified before processing according to embodiments of this invention. The green coffee beans can have sizes and geometries consistent with commercially available green coffee beans. In a one embodiment, the green coffee beans which can be dried and ground in the single-stage process have a moisture content generally in the range of about 6% to about 50%, particularly about 8% to about 45%, and more particularly about 10% to about 40%.

In one embodiment, moisturized green coffee beans are used as the feed material which generally contain about 20% to about 50% moisture, and particularly about 25 wt.% to about 35 wt.% moisture, when introduced into the cyclone **101** of system **100**, while the dried, roasted and ground coffee bean product generally contains about 2 wt.% to about 5 wt.% moisture. The premoistening treatment may be desirable in order to

induce enhanced beneficial flavor modification during the single-stage drying, roasting and grinding process. In another particular embodiment, green coffee beans having a moisture content of about 8% to about 15%, particularly about 10% to about 15%, are used as the feed material subjected to the single-stage process, while the dried, roasted and ground coffee bean product obtained therefrom generally contains about 2 wt.% to about 5 wt.% moisture. Ground coffee beans are obtained by the processes of this invention having commercially useful particle sizes. In one embodiment, the ground coffee beans obtained by processing according to this invention generally may have an average particle size of about 0.1 mm to about 4 mm. In one embodiment, the solid particulate product obtained as the bottoms of the cyclone comprise at least about 50% ground coffee beans have an average particle size of about 0.1 mm to about 1 mm.

In one embodiment, the processing of green coffee beans in accordance with embodiments of the present invention can be used to roast the beans an amount sufficient to lower the Hunter L-color of the beans at least about 10 color units, and particularly at least about 15 units, and more particularly at least about 20 units. The Hunter "L" scale values of the well-known Hunter color system are units of light reflectance measurement, and the lower the value is, the darker the color. Therefore, in measuring degrees of roast of coffee beans, the lower the "L" scale value the greater the degree of roast provided. Moreover, and for purposes herein, a change (i.e., reduction) in Hunter L-color generally is a direct indicator of the extent of roasting. The initial L-color of unroasted green coffee beans can vary depending on the type of bean or bean blend. For sake of illustration only, unroasted green coffee bean blend high in Robusta beans may have an initial L-color value of about 40 or higher. Green Robusta beans tend to be naturally darker than some other types of beans, but not necessarily for all cases. The process of embodiments of this invention can provide ground coffee bean product having a Hunter L-color between about 10 to about 24, particularly about 12 to about 20.

Although this invention has been illustrated for processing coffee beans, it will be appreciated that the methods and equipment arrangements of this invention are generally applicable to other agro-beans such as cocoa beans in general.

The Examples that follow are intended to illustrate, and not limit, the invention. All percentages are by weight, unless indicated otherwise.

Examples

Example 1:

Green coffee beans (Robusta) having a moisture content, as supplied, of about 12-15% were moisturized to provide moistened green coffee beans having a moisture content of 30%. Different portions of the moistened green coffee beans were fed into each of two different sizes of a WINDHEXE apparatus for circular vortex air flow material grinding. Each WINDHEXE apparatus was manufactured by Vortex Dehydration Systems, LLC, Hanover, Maryland, U.S.A. The basic configuration of that type of apparatus is described in published U.S. patent appln. publication no. 2002/0027173 A1, and reference is made thereto. The process unit had four inlet ports equidistantly spaced around the upper portion of the apparatus through which the compressed air stream was concurrently introduced in a counter-clockwise direction.

A two-foot diameter and a four-foot diameter WINDHEXE apparatus were tested. Two test runs were conducted on the 2-foot diameter apparatus, and one on the four-foot apparatus. The diameter size refers to the chamber size of the enclosure into which air and coffee bean introductions were made. The conditions of these tests are described below. For all tests, the feed rate of the moistened green coffee beans was set for an approximate discharge of 3 pounds solid product per minute, and approximately 20-25 pounds of green coffee bean material was tested in each size of apparatus for a given test run. The green coffee beans were loaded into a hopper that directly fed onto a three-inch belt conveyor that fed into the WINDHEXE apparatus. For all tests, the total amount of air being used was approximately 2,500 cubic feet per minute (cfm).

Test 1:

Testing was performed in the 2-foot diameter WINDHEXE apparatus with compressed air introduced at 410°F, a heated air introduction rate of 2,500 cfm and pressure of 25 psig. About 20 pounds of moistened green beans were introduced into the apparatus. The coffee product exiting the apparatus was lightly roasted and coarsely ground. The product exhibited distinct coffee notes (sniff testing) and a darkened hue in visual appearance (as compared to the green beans) which was indicative of light coffee bean roasting.

The coffee bean product from the first run (i.e., lightly roasted and coarsely ground) was passed through the apparatus again, and acquired a darker roasted product

with finer grind size, and still exhibited distinct coffee notes from an aroma standpoint.

Test 2:

Additional testing was performed in the 2-foot diameter WINDHEXE apparatus with compressed air introduced at 400°F, 2,500 cfm and 50 psig (input power 437 KWH). About 25 pounds of the moistened green beans (30% moisture) were introduced into the apparatus for this test. The process converted a portion of the coffee beans into a dry and powder-like material, which was recovered at the lower discharge end of the apparatus. The ground particles had a roasted appearance and had a coffee aroma. Some beans stayed relatively intact (i.e., little or nominal grinding), but exited at reduced moisture content (i.e., they were dried).

It will be appreciated that the partially dried oversized beans discharged with the solid particulate material at the lower end of the apparatus can be separated from the finer sized fraction by sieving techniques, and then the coarser fraction can be continuously recycled to the apparatus for reprocessing in the apparatus until dried and ground to the desired size.

Test 3:

Separate additional testing was performed in the 4-foot diameter WINDHEXE apparatus with compressed air introduced at 400°F, 2,500 cfm and 50 psig (input power 437 KWH). About 25 pounds of the moistened green beans (30% moisture) were introduced into the 4-foot cyclone for this test. The process converted a portion of the coffee beans into a dry and powder-like material. Some beans stayed intact, but at reduced moisture. The ground particles had a roasted coffee aroma.

Test 4:

A different supply of green coffee beans (Robusta, 8-10%) were moistened (30%), and then tested and evaluated in a similar manner under similar conditions as used in Test 1. The product obtained also exhibited distinct coffee notes and a darkened hue in visual appearance which was indicative of light coffee bean roasting. The coffee bean product from the first pass was passed through the apparatus again, and acquired a darker roasted product with finer grind size, and still exhibited distinct coffee notes from an aroma standpoint.

Example 2:

Green coffee beans (Robusta) having a moisture content, as supplied, of about 10-13% were subjected to single-stage treatment under conditions described below, and the product was organoleptically evaluated. The green coffee beans were fed into a 4 feet diameter WINDHEXE apparatus, such as generally described in Example 1, with compressed air introduced at 434°F, 2,500 cfm and 50 psig. The product discharged from the bottom of the system was collected and passed through the system a second time. The feed rate for the first pass was 8.5 lbs./min., and the feed rate for the second pass was 8.3 lbs./min. The product from the second pass was screened through a 12-mesh screen, and the fraction passing through the screen was organoleptically evaluated for color, flavor, and brew solids.

The ground product obtained from the second pass had a Hunter L-color value of 14, considered to correspond with a standard lightly roasted coffee product.

A sample of the ground product was brewed according to a standard coffee recipe (20 g ground product, one liter water) using a conventional Mr. Coffee® drip coffeemaker. The brew solids were 0.47% and the brew yield was 24%. Tasting of the brewed product revealed a distinctly detectable roasted coffee character and mild pleasing coffee flavor.

These examples demonstrated that both normal moisture and moistened green coffee beans were successfully roasted, ground and dried in a single process operation and in a single piece of equipment used in accordance with embodiments of the present invention. The feed rate of wet green coffee beans could be managed to control finished product granulation and moisture.

While the invention has been particularly described with specific reference to particular process and product embodiments, it will be appreciated that various alterations, modifications and adaptations may be based on the present disclosure, and are intended to be within the spirit and scope of the present invention as defined by the following claims.

Claims

1. A coffee bean heat treatment and grinding process, comprising:

introducing compressed heated air into an enclosure that includes a truncated conical shaped section, wherein the heated air travels along a downward path through the enclosure, including the conical section, to a lower end thereof, and the heated air reaching the lower end flows back up and exits the enclosure via an exhaust outlet;

introducing into the enclosure green coffee beans which are entrained in the heated air traveling downward through the enclosure, wherein at least a portion of the green coffee beans are dried, roasted, and ground before reaching the lower end of the enclosure;

discharging a solid particulate product including dried, roasted and ground coffee beans from the lower end of the enclosure.

2. The process of claim 1, wherein the green coffee beans contain about 6 wt.% to about 50 wt.% moisture when introduced; and the dried, roasted and ground coffee beans contain about 2 wt.% to about 5 wt.% moisture.

3. The process of claim 2, wherein the green coffee beans contain about 20 wt.% to about 50 wt.% moisture when introduced.

4. The process of claim 3, wherein the green coffee beans contain about 25 wt.% to about 35 wt.% moisture when introduced.

5. The process of claim 2, wherein the green coffee beans contain about 8 wt.% to about 15 wt.% moisture when introduced.

6. The process of claim 5, wherein the green coffee beans contain about 10 wt.% to about 15 wt.% moisture when introduced.

7. The process of claim 1, wherein the ground coffee beans have an average particle size of about 0.1 mm to about 4 mm.

8. The process of claim 1, wherein the green coffee beans are roasted under conditions in the enclosure sufficient to lower the Hunter L-color of the beans by at least about 10 L-color units.

9. The process of claim 1, wherein the green coffee beans are roasted under conditions in the enclosure sufficient to lower the Hunter L-color of the beans by at least about 15 L-color units.

10. The process of claim 1, wherein the introducing of the heated air comprises supplying compressed heated air at a pressure within the range of from about 10 psig to about 100 psig, and at a temperature within the range of about 300°F to about 700°F, and at a rate of within the range of from about 500 cubic feet per minute to about 10,000 cubic feet per minute.

11. The process of claim 1, wherein the introducing of the heated air comprises supplying compressed heated air at a pressure within the range of from about 15 psig to about 60 psig, and at a temperature within the range of about 400°F to about 650°F, and at a rate within the range of from about 1,500 cubic feet per minute to about 3,000 cubic feet per minute.

12. The process of claim 1, further comprising re-introducing at least a portion of the coffee beans in the solid particulate product into the upper enclosure for additional treatment therein.

13. A coffee bean heat treatment and grinding process, comprising:

introducing compressed heated air into an upper cylindrical enclosure wherein the heated air spirals along a downward path through the upper enclosure and into an adjoining lower enclosure having a truncated conical shape and a lower end, and the heated air flows back up and exits the upper enclosure via an exhaust outlet;

introducing into the upper enclosure green coffee beans containing about 6 wt.% to about 50 wt.% moisture which are entrained in the heated air spiraling downward through the upper and lower enclosures, wherein at least a portion of the green coffee beans are dried, roasted, and ground before reaching a lower end of the lower enclosure;

discharging a solid particulate product including dried, roasted and ground coffee beans from the lower end of the lower enclosure, wherein the dried, roasted and ground coffee beans contain about 2 wt.% to about 5 wt.% moisture.

14. The process of claim 13, wherein the green coffee beans contain about 20 wt.% to about 50 wt.% moisture when introduced.

15. The process of claim 13, wherein the green coffee beans contain about 8 wt.% to about 15 wt.% moisture when introduced.

16. The process of claim 13, wherein the green coffee beans are roasted under conditions in the enclosure sufficient to lower the Hunter L-color of the beans by at least about 10 L-color units.

17. The process of claim 13, wherein the ground coffee beans have an average particle size of about 0.1 mm to about 4 mm.

18. The process of claim 13, wherein the introducing of the heated air comprises supplying compressed heated air at a pressure within the range of from about 10 psig to about 100 psig, and at a temperature within the range of about 300°F to about 700°F, and at a rate of within the range of from about 500 cubic feet per minute to about 10,000 cubic feet per minute.

19. The process of claim 13, further comprising re-introducing at least a portion of the coffee beans in the solid particulate product into the upper enclosure for additional treatment in the upper and lower enclosures.

20. Roast and ground coffee product prepared from green coffee beans in a method comprising introducing compressed heated air into an enclosure that includes a truncated conical shaped section, wherein the heated air travels along a downward path through the enclosure, including the conical section, to a lower end thereof, and the heated air reaching the lower end flows back up and exits the enclosure via an exhaust outlet; introducing into the enclosure green coffee beans which are entrained in the heated air traveling downward through the enclosure, wherein at least a portion of the green coffee beans are dried, roasted, and ground before reaching the lower end of the enclosure; and discharging a solid particulate product including dried, roasted and ground coffee beans from the lower end of the enclosure to provide the roast and ground coffee product.

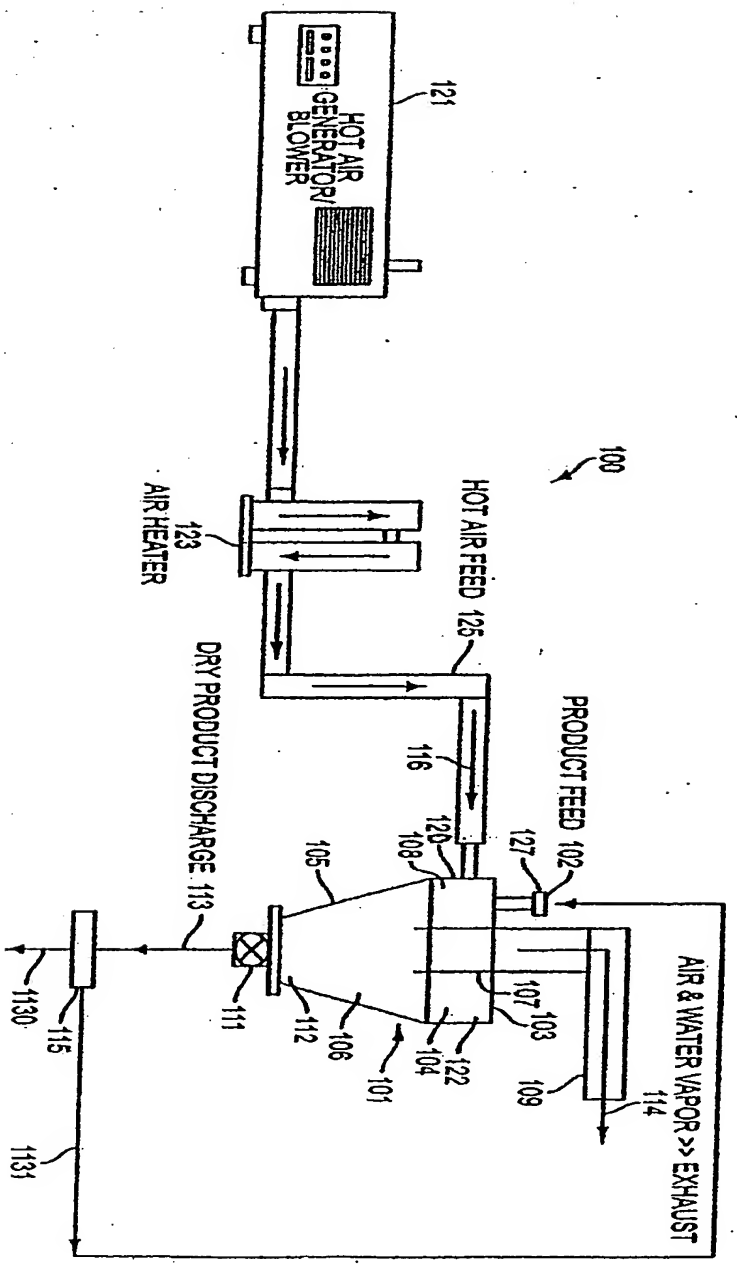
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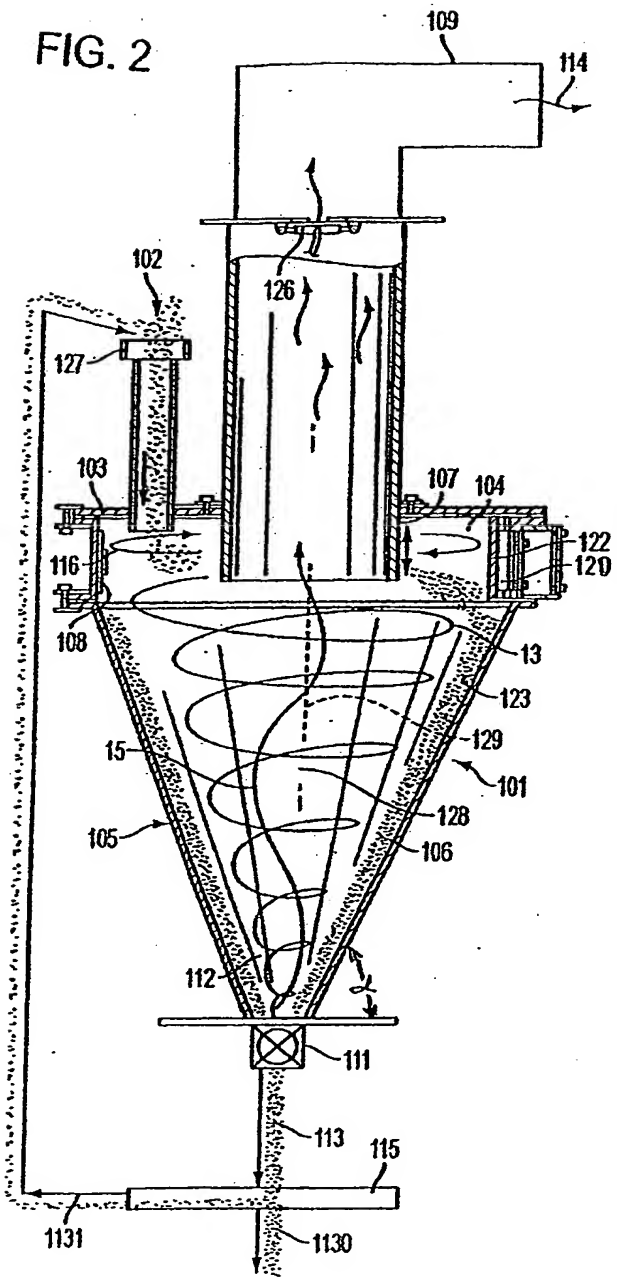
FIG. 1

FIG. 2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INTERNATIONAL SEARCH REPORT

Int ial Application No
PCT/US2004/042138

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A23N12/08

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A23N A23F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 00/56460 A (POLIFKA, FRANCIS, D) 28 September 2000 (2000-09-28) cited in the application	1,7-11, 16-18,20
Y		2-6, 13-15
A	page 2, line 20 - page 7, line 8 page 19, line 22 - page 20, line 2; claims 1,24-28; figure 2	12,19
Y	US 3 595 668 A (LEE NUTTING ET AL) 27 July 1971 (1971-07-27) column 8, line 3 - column 9, line 40; claims 1,2,4,5,7,8; figure 6	2-6, 13-15

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 May 2005	01/06/2005

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Hinrichs, W

INTERNATIONAL SEARCH REPORT

Int. Application No
PCT/US2004/042138

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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